Vertical Farm EDEN

Abstract

A Concurrent Engineering (CE) study at DLR has investigated the *Vertical Farming* concept. A *Vertical Farm* (VF) is the cultivation of plants in skyscrapers. Here, a significant increase in production of fresh vegetables and fruits per square meter footprint compared to conventional greenhouse can be achieved by implementing so-called Controlled Environment Agriculture (CEA) technologies.

The CE study objectives were to determine the technical and economic feasibility of a *Vertical Farm*. DLR aimed to apply its knowledge of CEA Technologies in space systems to prepare and present the first engineering design of a *Vertical Farm*. A 37 story building was designed with a multi-crop production strategy.

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Vertical Farm Concurrent Engineering Group

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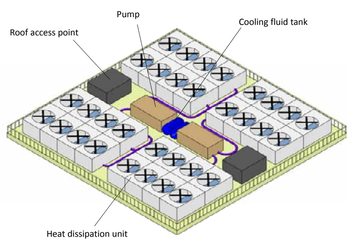
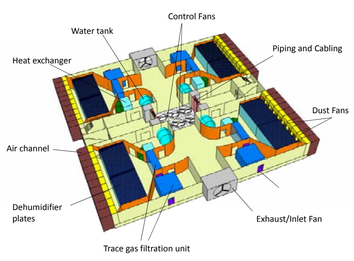
Environmental Control (Roof)



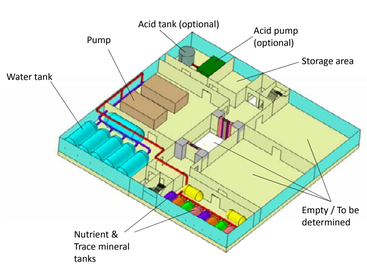
The heat load, which is removed from the air by heat exchangers, is vented to the roof where it is released to the environment via large heat dissipation units.

Environmental Control Floors



Maintains the desired air temperature and relative humidity, along with the desired CO_2 levels for the plant cultivation floors (PCF) to obtain maximum biomass yield. Used air is pumped to 3 separate environmental floors for processing; Fresh air is pumped through the main air shaft in the middle of the VF towards the PCF. Contaminants and trace gases are removed from the air through filters .

Nutrient Delivery Floor

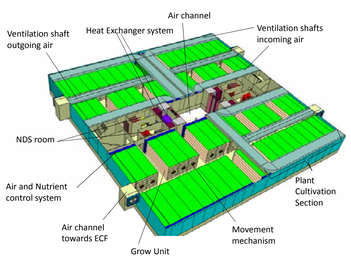


Aeroponic technology is used to provide nutrients to the plants.

Mix computers ensure that the correct quantities of nutrients are mixed with the desired amount of water.

The nutrient-water mixture is pumped to the plant cultivation floors.

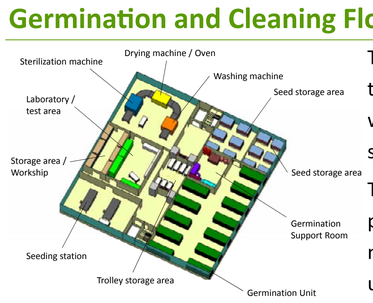
Plant Cultivation Floors



The 25 plant cultivation floors are the central production areas of the VF. A multi crop strategy (e.g. lettuce, cabbage, spinach, carrots, radish) is foreseen, but with one single crop type on each floor only.

Movable grow units are used to optimize grow space per floor while allowing proper access to each grow pallet.

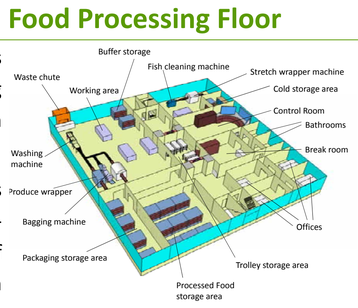
Germination and Cleaning Floor



The start of the plant life cycle is the germination phase, during which the first plant sprouting from seeds occur.

The germination floor enables proper seed germination. Furthermore, sterilization procedures of used grow pellets take place on this floor.

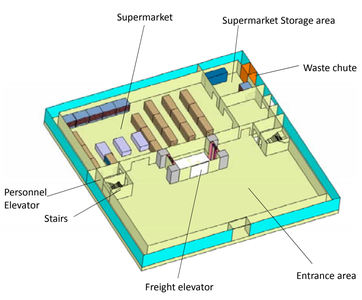
Food Processing Floor



Crops are inspected to check the quality, before cleaning and packaged for sale. Edible fish is placed in a fish cleaning machine, which removes the entrails, scales and other unwanted parts.

The floor also inhabits a *Vertical Farm* control room, employee's rooms and several storage rooms.

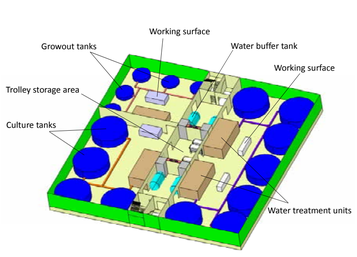
Supermarket and Delivery Area



People can buy the fresh food from the ground floor supermarket.

The floor is also be used by the forklift trucks to remove waste from the waste management floors, delivery of equipment & goods and outgoing shipments of food.

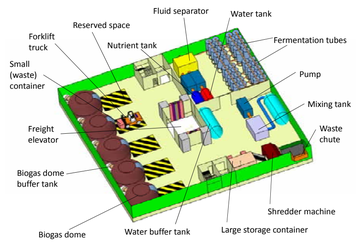
Fish Farming Floors



Fish (tilapia) breeding in 48 tanks across three levels. Five sizes allow the proper cultivation of different fish development stages.

Filter facilities on each floor, filter the water to remove waste, excess feed and other undesirable substances.

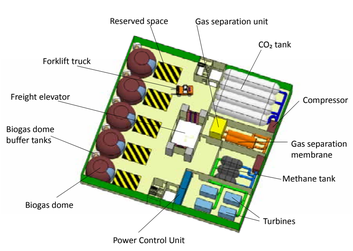
Waste Management Floor 1



Small waste containers are moved around to either the biogas domes or the fertilizer facility using forklifts.

The mixing tank is used to mix the shredded waste with water, before it is pumped into special fermentation tubes for nutrient extraction.

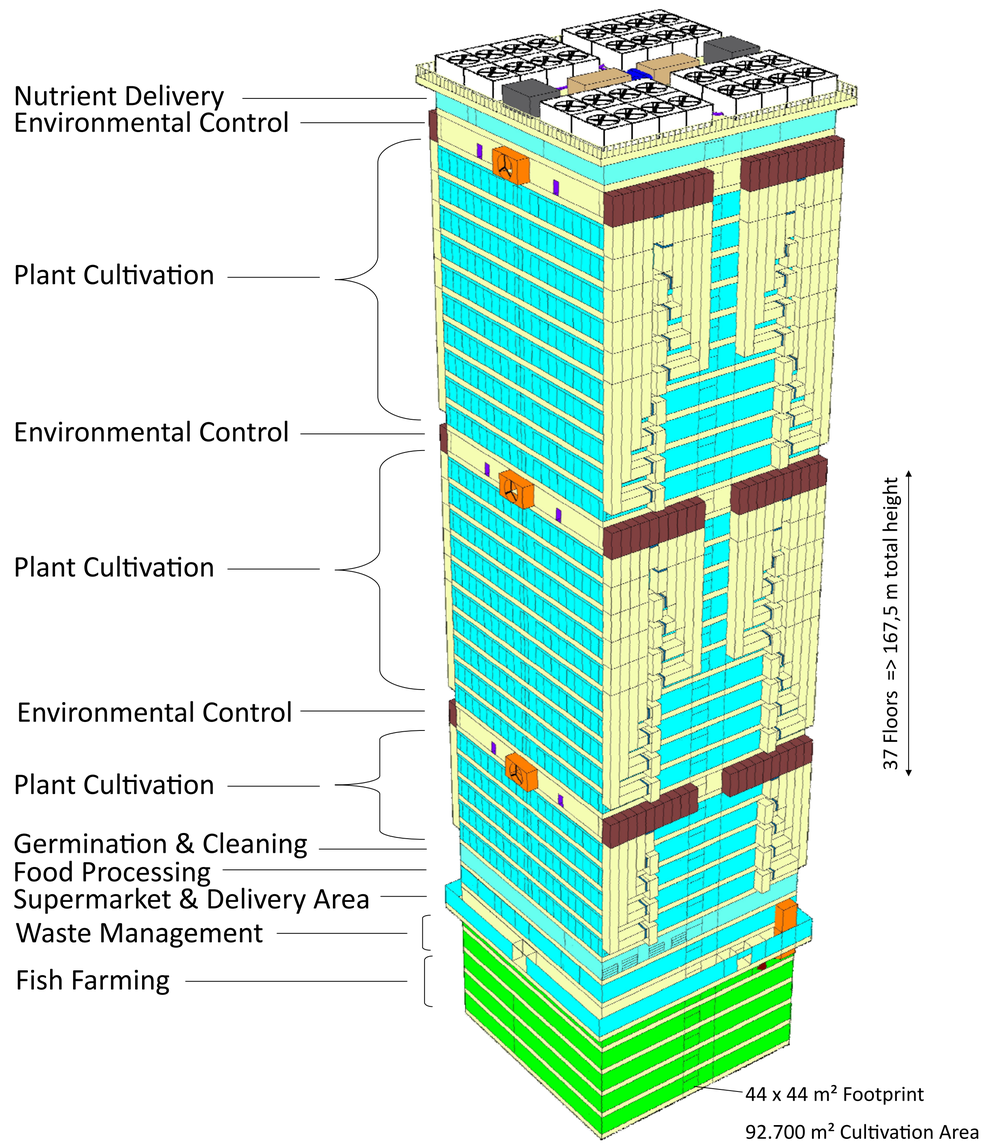
Waste Management Floor 2



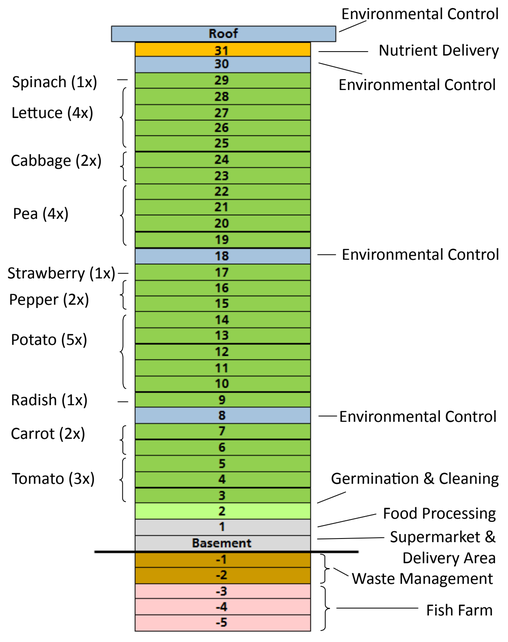
Gas from the biogas domes is led into a gas separation unit. Here, the biogas is split into carbon dioxide and methane gas.

The methane gas is burned to generate electrical energy, while the carbon dioxide is used for the plant cultivation.

Cross Section View



Advantages/ Challenges



Advantages

- Year-round crop production
- No weather related crop failures (wrt droughts, hail, heavy rain storms)
- Reduction in vehicular transport & crop spoilage (in-situ production)
- No use of insecticides and pesticides
- Elimination of agricultural runoff
- Possible evapotranspiration recovery
- Faster production and higher yields due to CEA
- Improved sustainability for urban centers
- Conversion of black or gray water to drinking water
- Provision of energy via methane generation
- Creation of new urban employment opportunities

Challenges

- High investment for setting up a *Vertical Farm*
- High energy demand & (fossil vs. renewable source)
- Requires additional CEA technology development

Input/ Output Comparison

Input

Resources	Consumption per year
Electricity:	150.800 MWh
Carbon dioxide:	464.000 m^3
Fertilizer:	11.000 l
High-protein fish feed:	131 t
Fish feed => inedible biomass:	365 t
Water:	8.275 m^3
Personnel:	60 people
Operation costs with 20% margin:	62.173 k€

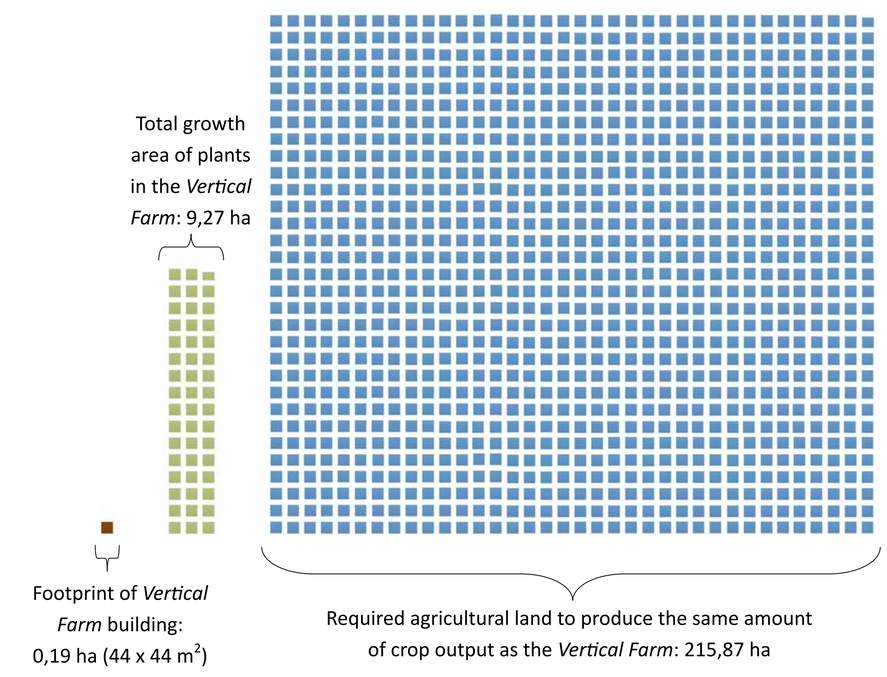
Output

Resources	Consumption per year
Electricity*:	2.838 MWh
Carbon dioxide*:	358.722 m^3
Inedible biomass*:	3.420 t
Inedible fish output*:	394 t
Methane*:	717.444 m^3
Total plant yield:**	4.854 t
Tilapia filet yield:	102 t

*in-house use **Total output of all crops e.g. Tomatoes, Lettuce, etc.

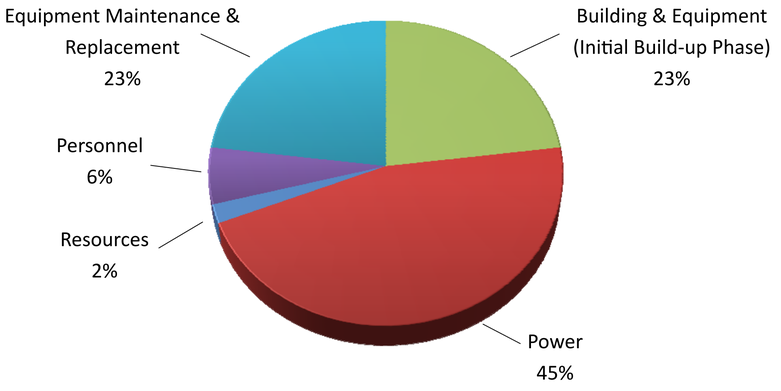
Vertical Farm compared to Traditional Agriculture

One square = 0,19 ha



Vertical Farm Cost Summary

Cost driver for the yearly Vertical Farm costs



The sales of the fresh fruit, vegetables and fish filet will be put towards the running and maintaince of the *Vertical Farm*. The cost per kilogram of produce was calculated using the annual cost.

Minimum required average food price: 12,54 €/kg

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